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Seed:Seedling Ratios of Engelmann Spruce After Clearcutting in the Central Rocky Mountains

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Seed:seedling ratios were determined at the end of the germination period, and after the first, and fifth growing seasons for Engelmann spruce, on four seedbed treatments and two aspects, on the Fraser Experimental Forest, Colorado. Seed to 5-year-old seedling ratios on the north aspect scarified-shaded (32:1), scarified-unshaded (76:1) and unscarified-shaded (72:1) seedbeds indicate that acceptable regeneration (eight hundred 5-year-old trees per acre) could be expected on 3- to 5-acre clearcut openings adjacent to an adequate spruce seed source and, not more than 5- to 6-tree heights wide. Seed to 5-year-old seedling ratios on the unscarified-unshaded north aspect seedbeds, and all seedbed treatments tested on the south aspect were so high that restocking of any opening large enough to be considered a clearcut is questionable.

Keywords: *Picea engelmannii*, regeneration, seed:seedling ratios, seedbed treatment

The uncertainty of successful natural regeneration of Engelmann spruce (*Picea engelmannii* Parry ex. Engelm.) after clearcutting spruce-subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) forests is a major management concern in the central Rocky Mountains (Alexander 1974). There are three basic requirements for regeneration success: (1) an adequate supply of seed, (2) a suitable seedbed, and (3) an environment compatible with germination and survival (Roe, et al. 1970). Although past research and observations most often have identified environment as the most limiting factor (Noble and Alexander 1977), relatively little effort has been directed toward determining the supply of Engelmann spruce seed required for an acceptable stocking level for a particular site. Seed:seedling and seedling:seedling ratios previously determined for spruce have been averages for a wide range of site conditions (Noble and Ronco 1978).

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The determination of what is an adequate supply of spruce seed must be based on reliable estimates of (1) the amount of sound seed available, and (2) seed:seedling ratios after stocking levels have become relatively stable. Seed:seedling ratios vary considerably, depending upon seedbed condition, and environmental, biotic and management factors.

This note reports the ratio of sound seeds to newly germinated, and 1- and 5-year-old seedlings in relation to aspect and seedbed treatments. It is part of a larger study of the effects of environmental factors on the natural regeneration success of Engelmann spruce. Because methodology has been reported elsewhere (Noble and Alexander 1977), only necessary detail is reported here.

Study Areas

Field observations were made from 1968 through 1982, on the Fraser Experimental Forest in central Colo-

rado, on two areas approximately 4.5 miles apart. One is on a north and the other is on a south aspect at about 10,500 feet elevation. Both areas are enclosed within 100- × 110-foot hardware-cloth rodent exclosures (Noble and Alexander 1975) in the center of 3.5-acre square clearcut openings in spruce-fir stands (fig. 1). The hardware cloth generally excluded deer mice (*Peromyscus maniculatus* Wagner), red-backed voles (*Clethrionomys gapperi* Vigors), mountain voles (*Microtus montanus* Peale), western chipmunks (*Eutamias minimus* Bachman), and pine squirrels (*Tamiasciurus hudsonicus fremonti* Audubon and Bachman); but not pocket gophers (*Thomomys talpoides* Richardson) or birds that feed on tree seeds, such as the grey-headed junco (*Junco caniceps* Woodhouse) (Noble and Shepperd 1973). The habitat type is *Abies lasiocarpa/Vaccinium scoparium*, the most common spruce-fir habitat type in Colorado. Moreover, the *Vaccinium* union does not compete as severely with tree seedlings as in some other habitat types.

Soils on both areas are gravelly, sandy loams developed in place under spruce-fir or mixed spruce-fir and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands from coarse-textured material weathered from mixed gneisses and schists (Retzer 1962). Average depth to the C horizon is 12 to 24 inches, including 3 to 4 inches of organic matter. Soil moisture at tensions of 1/3 and 15 bars is about 18% and 9%, respectively.

Methods

Experimental Design

The design is a two- by two- factorial replicated over 10 years time in randomized blocks. A set of twelve 1/4-mil^2 acre square (10.89 ft^2) seedbeds (four seedbed treatments replicated three times) were prepared on each aspect, each year from 1968 through 1977.

Seedbed Treatments

The four seedbed treatments were (1) scarified-shaded, (2) scarified-unshaded, (3) unscarified-shaded, and (4) unscarified-unshaded (Noble and Alexander 1977). Plots were scarified by hand to remove all organic material to mineral soil. Scarification simulated scalping with a dozer blade. Wooden frames made from 2-inch-wide furring strips with alternate 2-inch spaces, elevated 8 to 10 inches above the ground on metal framing, provided overhead shade. Slots of the shade frames were oriented in a north-south direction to provide alternate periods of shade and sunlight (fig. 2).

Seeding

The Engelmann spruce seed used in this study was collected locally. New collections were made only when

Figure 1.—Study area on the north aspect, after rodent exclosure was installed, but before seedbed treatments were in place.

Figure 2.—Shade-frame in place on north aspect shaded-scarified seedbed treatment.

stored seed viability dropped to less than 60%. In late September of each year (1968 to 1977), an estimated 125 viable seeds were evenly broadcast on each seedbed. The total number of seeds sown per seedbed each year varied from 165 to 210, depending on viability determined from laboratory germination tests. The seeds were not covered, because the intent was to simulate natural regeneration. The number of seeds sown corresponds to 500,000 sound seeds per acre, which can be expected from a heavy natural seedfall (Alexander et al. 1982). Plots were located at least 150 feet from the nearest timber edge to minimize the input of seed from adjacent timber stands. However, the seed:seedling ratios calculated should be considered minimums, especially because they are extrapolated from a heavy seedfall production.

Measurements

During the first growing season after each sowing, germination, survival and mortality were recorded at least twice weekly; after the first growing season, counts were made weekly. Measurements were begun in mid-June, when the plots were first clear of snow, and ended about mid-October, with the onset of winter snow cover.

Results and Discussion

Germination and seedling establishment was best on the treated seedbeds on the north aspect. The lowest seed:seedling ratios were on the scarified-shaded seedbeds, where treatment was most effective in conserving moisture by lowering temperatures of both soil and seedlings, and reducing competing vegetation.

Neither shade or scarification was as effective in conserving moisture as the combination of shade and scarification on the north aspect; fewer seeds germinated and fewer seedlings survived on the scarified-unshaded and unscarified-shaded seedbeds. Survival stabilized on all treated seedbeds by the fifth growing season, but it required nearly 2.5 times as many seeds to produce a 5-year-old seedling on the scarified-unshaded and unscarified-shaded seedbeds as on the scarified-shaded seedbeds (table 1).

The highest seed:seedling ratios on the north aspect were on unscarified-unshaded seedbeds. Thirteen times as many seeds were required to produce a 5-year-old seedling as on scarified-shaded seedbeds (table 1).

On the south aspect, the lowest seed:seedling ratios were on the scarified-shaded and unscarified-shaded seedbeds. Seed:germinating seedling ratios were higher on the unscarified-shaded seedbeds, but first year survival was lower. Seedling survival stabilized by the fifth growing season on these seedbeds, but compared to comparable seedbed treatments on the north aspect, it required more than 10 times as many seeds on scarified-shaded seedbeds, and nearly 5 times as many on the unscarified-shaded seedbeds to produce a 5-year-old seedling (table 1).

Few seeds germinated and no seedlings survived as long as five growing seasons on either the scarified-

Table 1.—Seed to seedling ratios at the end of germination, and the first, and fifth growing seasons by seedbed treatment and aspect

Aspect	Seedbed treatment	Germinating seedlings			First year survival[1]			Fifth year survival[2]		
		Mean	Range	%	Mean	Range	%	Mean	Range	%
N	Scarified shaded	11:1	5:1 to 94:1	9	18:1	9:1 to 188:1	59	32:1	10:1 to 375:1	57
	Scarified unshaded	15:1	8:1 to 94:1	6	33:1	14:1 to 188:1	47	76:1	16:1 to ∞	44
	Unscarified shaded	17:1	5:1 to ∞[3]	6	37:1	17:1 to ∞	45	72:1	29:1 to ∞	52
	Unscarified unshaded	42:1	9:1 to 375:1	2	125:1	54:1 to ∞	34	417:1	75:1 to ∞	30
S	Scarified shaded	35:1	9:1 to ∞	3	156:1	42:1 to ∞	22	341:1	75:1 to ∞	46
	Scarified unshaded	74:1	10:1 to ∞	1	1875:1	188:1 to ∞	4	∞		0
	Unscarified shaded	19:1	4:1 to 375:1	5	144:1	14:1 to ∞	13	312:1	54:1 to ∞	46
	Unscarified unshaded	46:1	9:1 to ∞	2	750:1	94:1 to ∞	6	∞		0

[1]*Ratio of germinating seedlings to survival at the end of the first growing season.*
[2]*Ratio of seedlings alive at the end of the first growing season to seedlings alive at the end of 5 growing seasons.*
[3]*∞ = no germination or survival.*

unshaded or unscarified-unshaded seedbeds on the south aspect (table 1). Germination was low because seedbeds were too cold immediately after snowmelt, and by the time they were warm enough for seedlings to emerge, the seedbeds were too dry. Moreover, water losses from soil and seedlings were so great that reducing air and soil temperatures by shading to conserve moisture was absolutely essential to any survival, regardless of the seedbed.

Eight hundred seedlings per acre at age 5 years is a reasonable stocking goal for Engelmann spruce (Alexander and Edminster 1980). This is more than required for adequate stocking, but necessary to achieve uniform spacing, allow for possible future mortality, and provide options in selecting crop trees in subsequent thinnings. Numbers of seeds, based on seed to 5-year seedling ratios in table 1, required to produce this stocking level under different seedbed conditions on north and south aspects are shown in table 2.

Data presented in Tables 1 and 2 are minimums, based upon the exclusion of seed-eating small mammals, but not birds that consume tree seeds. All spruce-fir forests support populations of these small mammals, and any disturbance that initiates understory plant succession probably favors a buildup of these populations, particularly if slash and other downed materials are present to provide cover. Although these mammals consume considerable seed, the magnitude of losses to them is not known in the central Rocky Mountains. However, losses to seed-eaters are more important in years of poor seed production, or years of high seed-eating mammal populations.

Several studies of seed predation by small mammals have been made elsewhere. For example, a study on the H. J. Andrews Experimental Forest in western Oregon, from 1955 to 1967, showed that losses to seed-eaters were substantial. About 25% of the western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) viable seed, and about 65% of the Douglas-fir (*Pseudotsuga. menziesii* (Mirb.) Franco) seed were consumed by small mammals (Gashwiller 1967, 1970). Although conditions are different in the Pacific Northwest, it seems reasonable to expect that under poorest conditions in the central Rocky Mountains, losses could be as high as 50% of the viable seed produced in a good seed year.

Table 2.—Number of viable seeds required to produce 800 five-year-old Engelmann spruce seedlings in relation to seedbed treatments and aspect[1]

Aspect	Seedbed Treatments: Scarified shaded	Scarified unshaded	Unscarified shaded	Unscarified unshaded
N	25,600	60,800	57,600	333,600
S	272,800	∞[2]	249,600	∞

[1]*Data presented are based upon the exclusion of seed-eating mammals. If these animals are not excluded, numbers of seed required should be increased by 50%.*
[2]*∞ = no survival.*

Engelmann spruce seed production on the Fraser Experimental Forest for a 10-year period (Alexander et al. 1982) is shown in the following tabulation:

Year	Number of viable seeds per acre in thousands
1970	342
1971	208
1972	281
1973	19
1974	271
1975	193
1976	15
1977	1114
1978	96
1979	13

Engelmann spruce seed dispersal studies in the central Rocky Mountains indicate that only about 10% of the sound seeds produced under uncut stands are dispersed as far as 300 feet into openings from the windward timber edge (Alexander and Edminster 1982). Based on estimates of potential seed production, and allowing for possible losses of 50% of the sound seed to seed-eaters and the reduction in seedfall as distance from source increases, seed to 5-year-old seedling ratios are adequate to restock all treated seedbeds on the north aspect, after clearcutting small openings 5 to 6 times tree height (400- to 450-feet wide), in an *Abies lasiocarpa/Vaccinium scoparium* habitat type.[2]

Restocking on a north aspect on scarified-shaded seedbeds should be possible within a 5-year period but may require more than 1 good seed year.[3] It will require a number of good seed years to restock scarified-unshaded and unscarified-shaded seedbeds, and it is not likely to be accomplished within a 5-year period. Unscarified-unshaded seedbeds in small clearcut openings on north aspects are not likely to adequately restock within a 20-year period.

On south aspects, no opening large enough to be a clearcut is likely to adequately restock regardless of the seedbed condition, in a reasonable amount of time.

Management Cautions

These data are derived from one habitat type at one location, the Fraser Experimental Forest. In the absence of better information, they can be used to approximate what might occur on similar seedbeds in this habitat type elsewhere. The following items should be kept in mind, however.

1. The viability of seed used in this study was good, but the criteria that 125 viable seeds were sown on each seedbed each year was based on laboratory germination tests. Actual viability in the field may have been lower, in which case the seed:seedling ratios are too low.
2. Small mammals that consume tree seed were excluded from this study. Exclosures suitable for research purposes are not practical for operational timber sales. The effectiveness of other rodent abatement procedures, such as treating seed or baiting, is not known for spruce-fir forests in the central Rocky Mountains. Moreover, little is known about seed predation by small mammals in spruce-fir forests. Estimates of possible losses to seed-eaters are highly speculative.
3. Estimates of seed production and dispersal are based on reliable data, but they are for relatively short periods of time and the number of viable seeds produced and the number dispersed a given distance from a source is highly variable from year to year and place to place.
4. Seed:seedling ratios vary considerably with climatic changes. These data cover a period of time 1968 to 1982, but represent only the weather conditions during that period. The distribution of summer precipitation varied more than the amount. Summer rainfall was more erratic during the period 1974 through 1980 than either before or after. No seedlings that germinated after 1973 survived on the south aspect.

These seed:seedling ratios are only estimates; their accuracy will vary from place to place and year to year, and should be checked on-the-ground.

[2]*Studies of spruce seed dissemination in the central Rocky Mountains indicate that 10 % or less of the viable seed produced by stands around the perimeter of clearcut openings will be dispersed as far as 300 feet from the windward edge (Alexander 1969, Noble and Ronco 1978).*

[3]*A good seed year produces 100,000 to 250,000 sound seeds per acre under uncut stands.*

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